Geology of the West Yamato Nunataks,* East Antarctica

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東南極大陸，西やまとヌナタクス*の地質

白　石　和　行**

要旨：第14次南極越冬隊の内陸調査隊は，1973年12月にやまと山脈南西方30 kmにある，7つのヌナタク群を踏査した．このヌナタク群はおのおの300～1,000mの広がりをもつが，大部分はモレーン堆積物でおおわれている．最高峰は2,282 mで，氷床からの比高は150 mにすぎない．

当地域にみられる岩石は，やまと山脈のものと類似しているが，チャーノッカイト類は認められない．最北端のヌナタクは，普通角閃石黒雲母片麻岩からなり，他のヌナタクは花崗岩質片麻岩類が広く分布する．変塩基性岩，花崗岩質岩脈，ペグマタイトは，全地域にみられる．

岩石の産状およびこの地域の構造的特徴から，当地域の地質は，ベルジカ山脈の地質と密接に関係しているものと思われる．

Abstract: Seven nunataks, provisionally named the West Yamato Nunataks, located at 30 km southwest of A group of the Yamato Mountains were briefly investigated by the present author in 1973. The heighest peak is 2, 282 m above sea level but the relative height from the ice surface is only 150 m.

The rocks exposed in the nunataks are similar to those of the Yamato Mountains except the fact that no charnockitic rocks are found. Hornblende-biotite gneiss is developed in the northernmost nunatak, while granitic gneiss is distributed in the other nunataks. Metabasites, granitic dykes and pegmatites occur throughout the whole area.

The occurrences of these gneisses as well as the structural characteristics may suggest a close geological relation between this area and the Belgica Mountains located about 150 km southwest of these nunataks.

1. Introduction

The 14th Japanese Antarctic Research Expedition (1973–1974) sent out the inland traverse party to the Yamato Mountains region, and three members of the

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party including the present author surveyed briefly the geomorphology and geology of the nunataks which are located at 30 km southwest of the Yamato Mountains during December 13 to 18, 1973.

A few of these nunataks had been already sighted from the Yamato Mountains by the 4th (1960) and the 10th (1970) Japanese Antarctic Research Expeditions, but the actual survey of the nunataks was carried out for the first time by the present party.

The nunataks lie between 71°49′S and 72°04′S in latitude and between 34°50′E and 35°20′E in longitude approximately, about 30 km southwest of A group of the Yamato Mountains, East Antarctica (Fig. 1). The area is composed of seven nunataks, which are temporarily named I to VII including moraine fields (Fig. 2).

The linear arrangement of Nunataks I, II, III, V and VI in the direction of N30°W, is almost parallel to that of the Yamato Mountains, and the direction also agrees with the general trend of the foliation of the rocks exposed in the present area. On the other hand, Nunataks IV, V, VI and VII are exposed along the ice step which stretches from the southern part of the A group of the Yamato Mountains toward the southwest of the inland (Fig. 3).

The surface of the ice sheet is 1,900 m to 2,100 m above sea level, and the height decreases from south to north. The average relative height of the nunataks

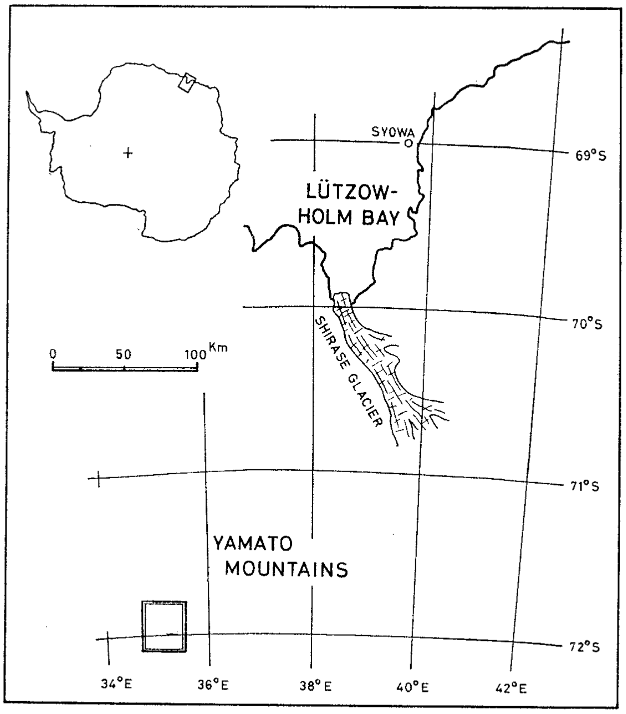

Fig. 1. The general situation of the surveyed area.

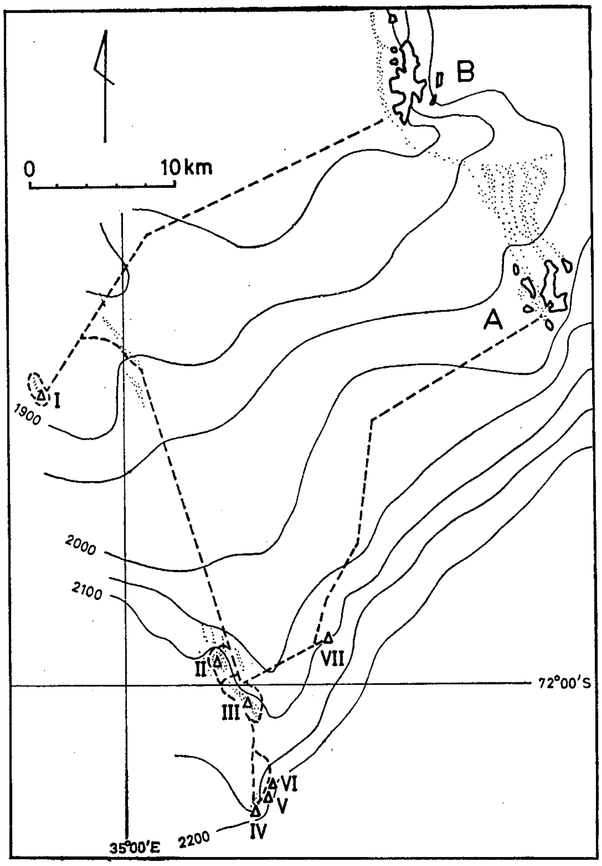

Fig. 2. The positional relations of the nunataks. A broken line shows the surveyed route, and dotted areas show moraine fields.

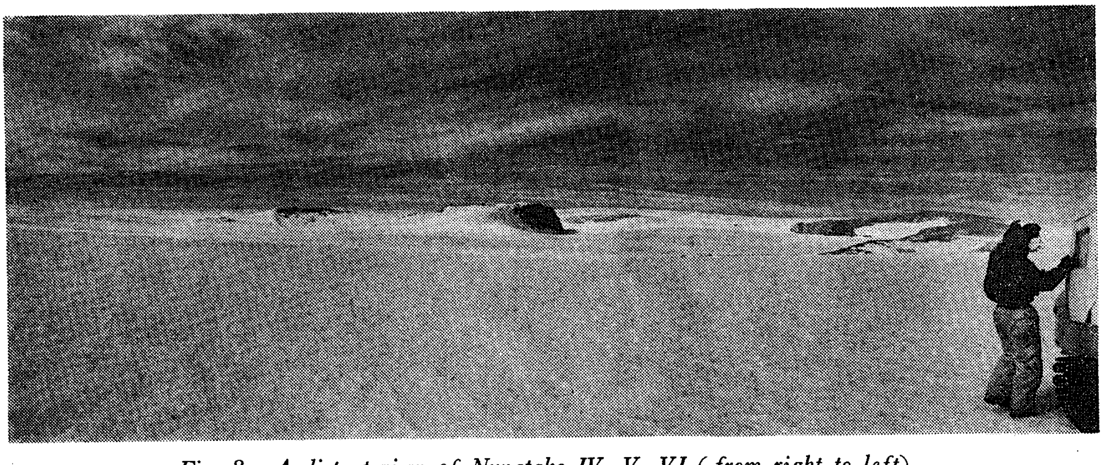

Fig. 3. A distant view of Nunataks IV, V, VI (from right to left).

is 100 m from the ice surface, and the heighest point, at Nunatak IV, is 150 m which means 2, 282 m above sea level.

All of the nunataks have been considerably glaciated to form flat and smooth surfaces, and their surfaces are usually covered by thick morainic debris except Nunatak I. Therefore, the geological survey was conducted mainly on the well exposed cliffs and precipices.

The occurrence of rocks in the field and the results of the laboratory study are briefly reported in the present paper.

2. General Geology

The rocks exposed in this region are similar to those of the Yamato Mountains, except that no charnockitic rocks are developed. They are classified as follows:

1) Hornblende-biotite gneiss
2) Granitic gneisses
3) Metabasites
4) Granitic dykes and pegmatites
5) Moraine deposits

Geological sketch maps of this region are shown in Figs. 4 to 9.

Hornblende-biotite gneiss occupies mainly Nunatak I, the northernmost one. The gneiss represents various migmatitic structures (Fig. 10). Megascopically the foliation trends rather uniformly and dips to north monoclinally. The gneiss is obliquely cut by granitic dykes and pegmatites of 20 to 30 cm in width.

Granitic gneisses which bear characteristically pinkish potassium feldspars of comparatively coarse grain and purple-grey quartz, occur in the whole region except

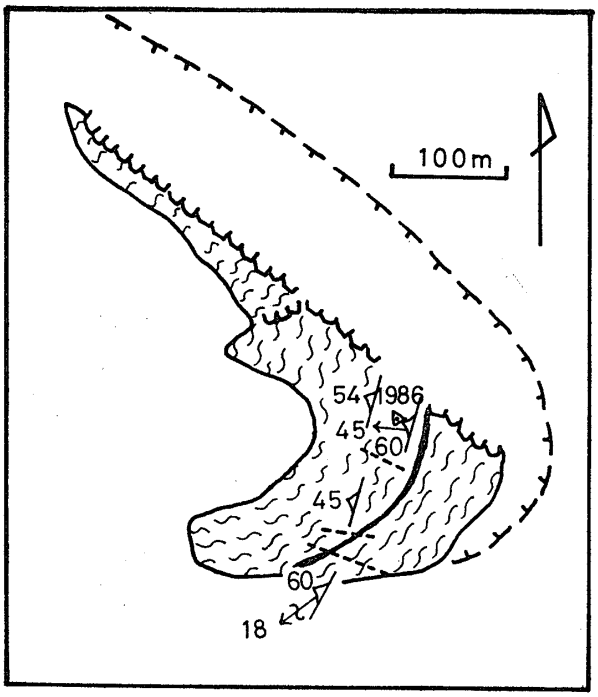

Fig. 4. Geological sketch map of Nunatak I.

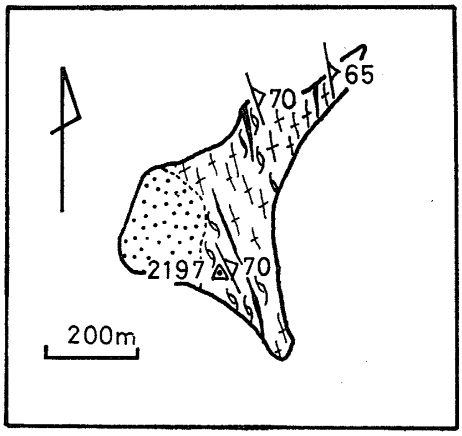

Fig. 5. Geological sketch map of Nunatak II.

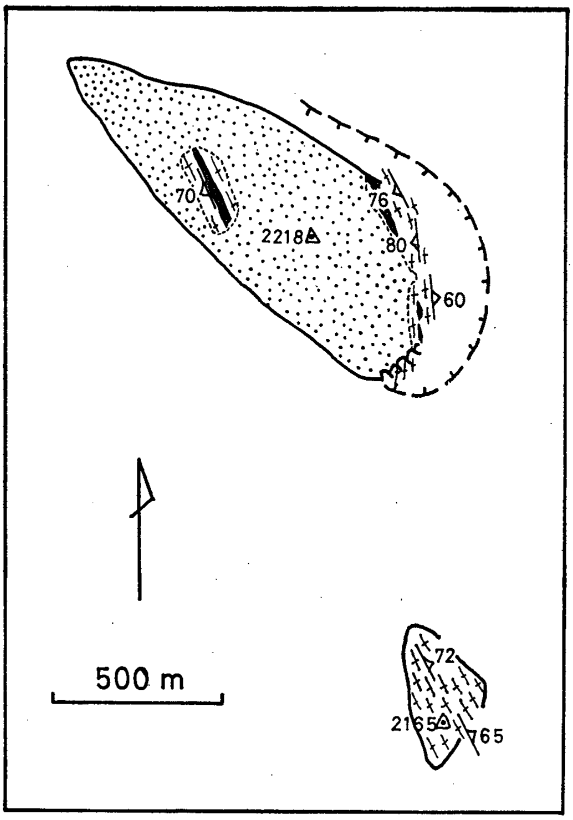

Fig. 6. Geological sketch map of Nunatak III.

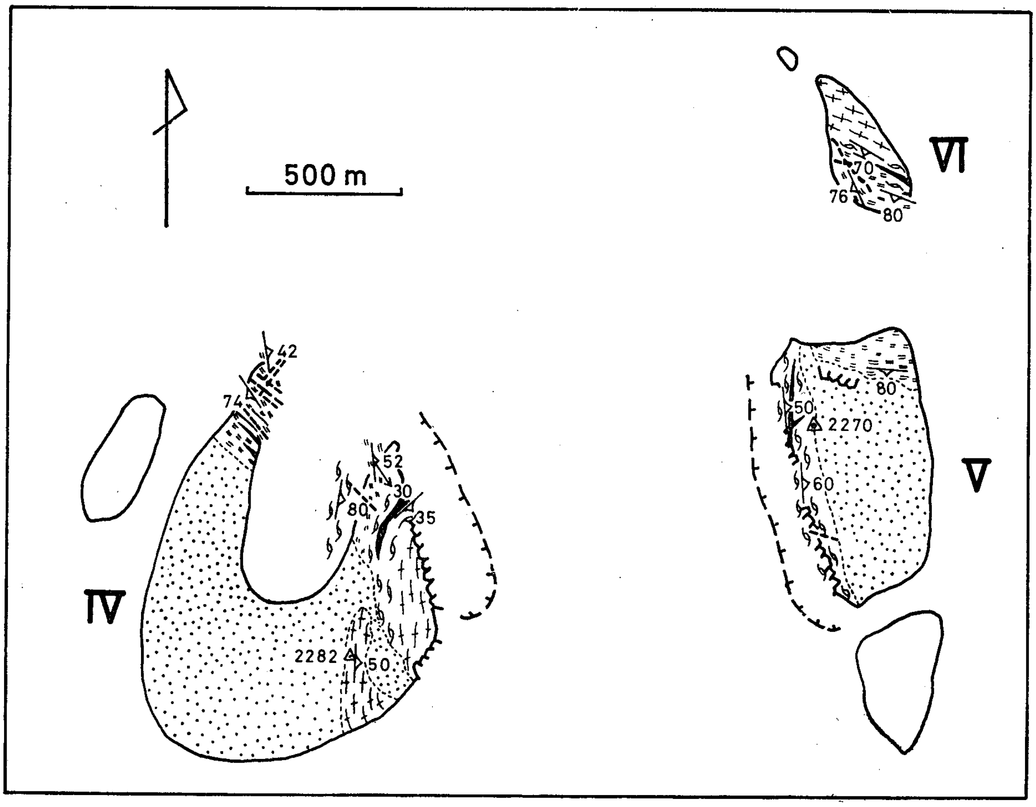

Fig. 7. Geological sketch map of Nunataks IV, V, VI.

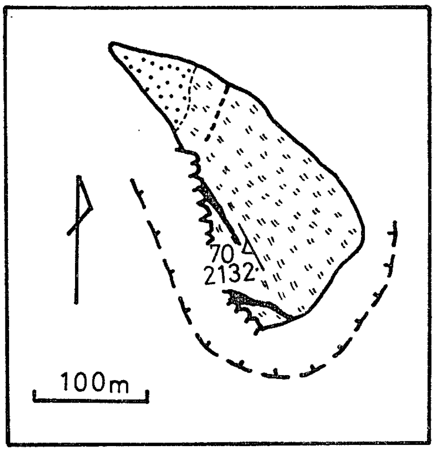

Fig. 8. Geological sketch map of Nunatak VII.

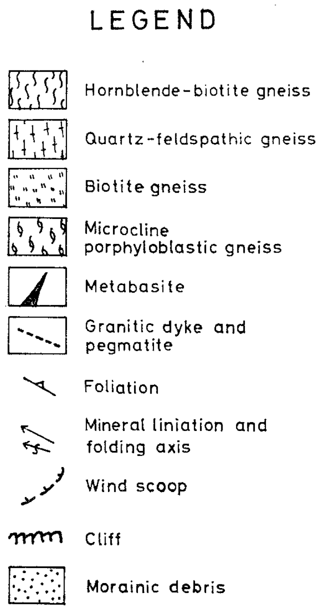

Fig. 9. Legend of Fig. 4 to Fig. 8.

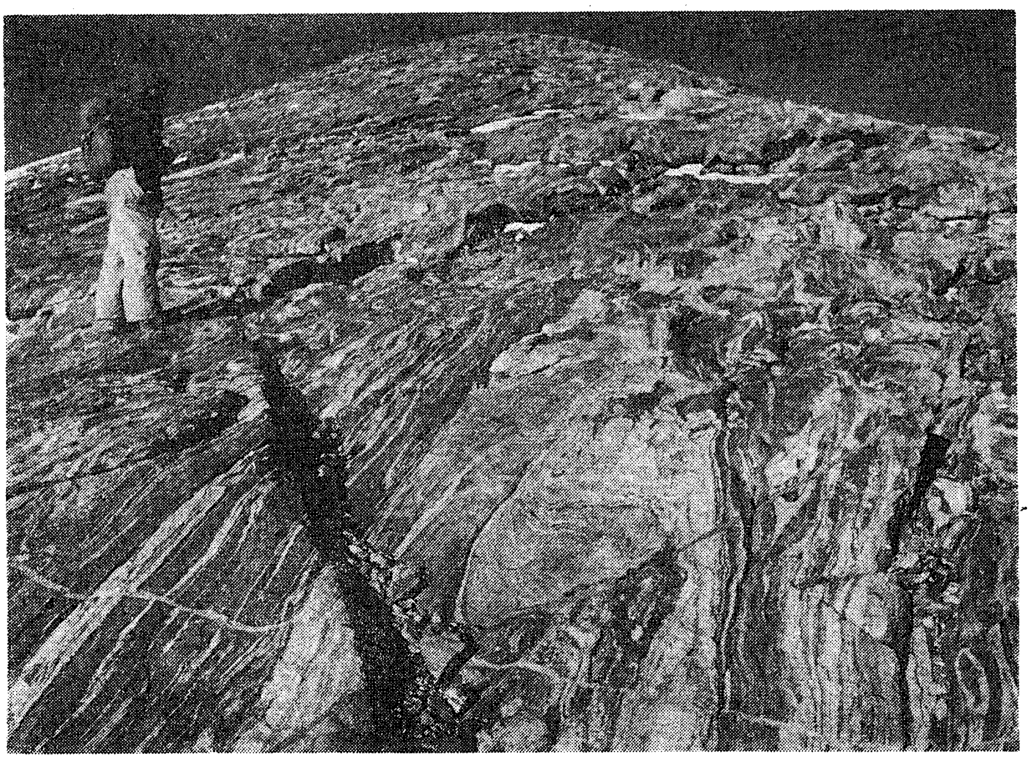

Fig. 10. Hornblende-biotite gneiss (Nunatak I).

Nunatak I. They are classified into three types by the features in handspecimens, i. e. 1) quartzo-feldspathic gneiss 2) biotite gneiss and 3) microcline porphyroblastic gneiss. The relation between hornblende-biotite gneiss and granitic gneisses is not clear because Nunatak I is apart almost 25 km from other nunataks. Locally the granitic gneisses show schollenic, schlierenic and folded structures. They are also cut by many aplitic veins, granitic dykes and pegmatites (Fig. 11).

Fig. 11. Granitic gneiss cut by aplitic veinlets (Nunatak V).

Metabasites occurring throughout the whole area are divided into two types by the occurrence. One (Type I) is sheets more or less concordant to the foliation of the country rock, ranging from 4 to 10 m or more in width. The contact of the metabasite and other rocks does not always show a distinct boundary due to partial migmatization (Fig. 12). The rock is cut by many granitic and aplitic veins. Agmatitic, banded and sometimes giant-eye structures are developed. The other (Type II) is dykes ranging from 0.3 to 3.0 m in width and cutting across the foliation of the country rock with clear contact. In Nunatak V, it is found that Type I is clearly cut by Type II (Fig. 13).

Throughout the whole area, there are many granitic dykes and pegmatites intruded at the later stage. They are generally a few decimetres in width, and have a sharp boundary with the country rocks. At Nunatak IV granitic dykes are parallel or projecting parallels arranged at intervals of 5–10 m. The agmatitic structure was produced resulting from the intrusion of a granitic dyke along the metabasite (Type II) in Nunatak II (Fig. 14). The direction of granitic dykes is

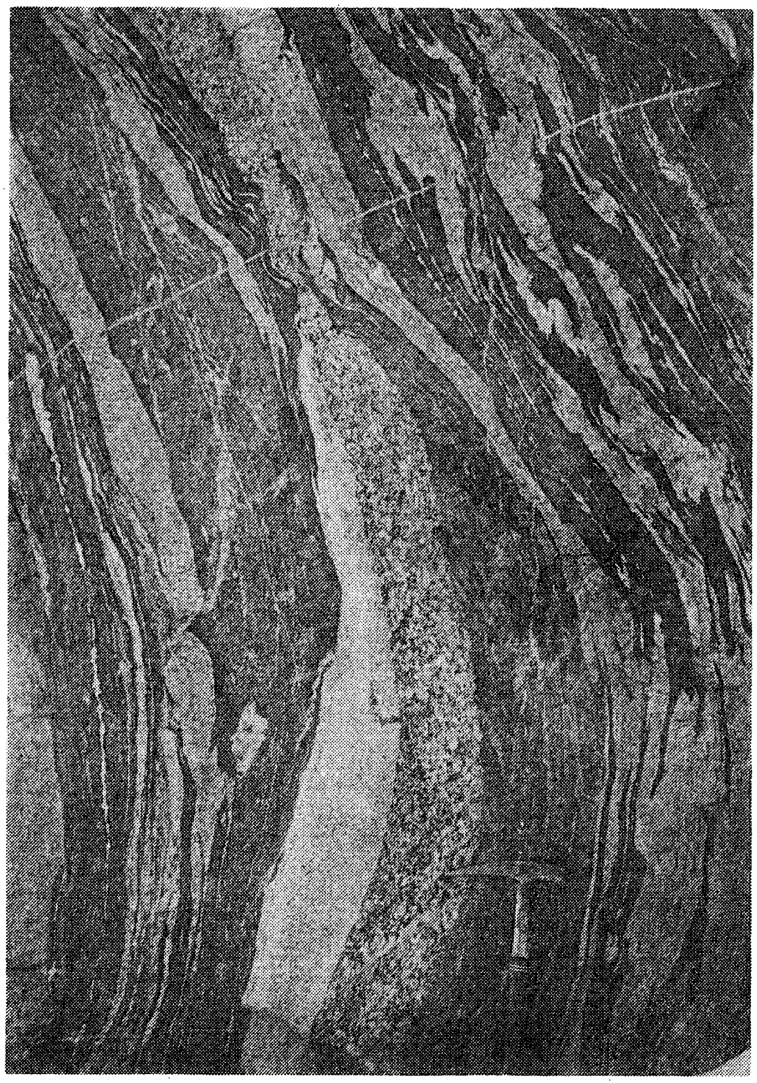

Fig. 12. Migmatized margin of metabasite (Type I) (Nunatak III).

WNW-ESE in Nunatak I, and NW-SE is predominant in Nunatak IV. Pegmatites occur in an irregular pool-like form in the biotite gneiss (Fig. 15).

In Fig. 16 the poles of the foliation of each nunatak are plotted on a Schmidt's equal-area net. The trend of the foliation is rather similar except Nunatak I.

In Nunatak I where hornblende-biotite gneiss is developed, the foliation is almost uniform in trend, mostly NE-SW, and dips 45°- 60° to the north. However, in the others the foliation generally trends NW-SE and it dips more steeply.

The greater part of these nunataks is covered by morainic debris consisting of angular to subangular fragments which are variable in size and sometimes boulders as large as two metres across are found. Among the fragments, granitic gneisses are dominant, with subordinate amounts of garnet-biotite-hornblende gneiss, metabasite and pegmatite.

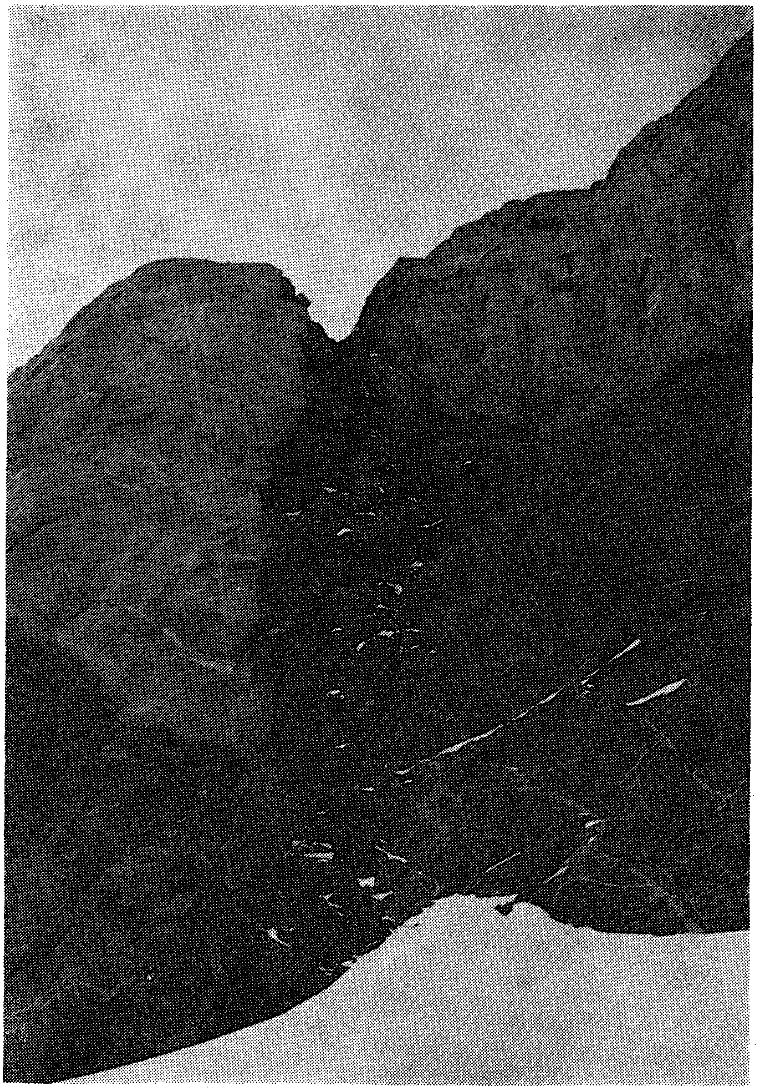

Fig. 13. Metabasite (Type I) cut by metabasite (Type II) (Nunatak V).

3. Petrography

Modal compositions of the main rock types are shown in Table 1.

3.1. Hornblende-biotite gneiss

This rock occurs only in Nunatak I. Hornblende-biotite gneiss consisting of fine-grained melanosome and fine- to medium-grained leucosome has a heterogeneous appearance, with migmatitic structures being banded, schlierenic and folded. Melanosome is predominant as a whole.

Aggregates of garnet, 0.5 to 1.0 cm in grain size, are sometimes found in the crest of fold. The foliation of melanosome is shown by quartzo-feldspathic layers of 0.5–5.0 cm in width though the melanosome itself does not clearly show the

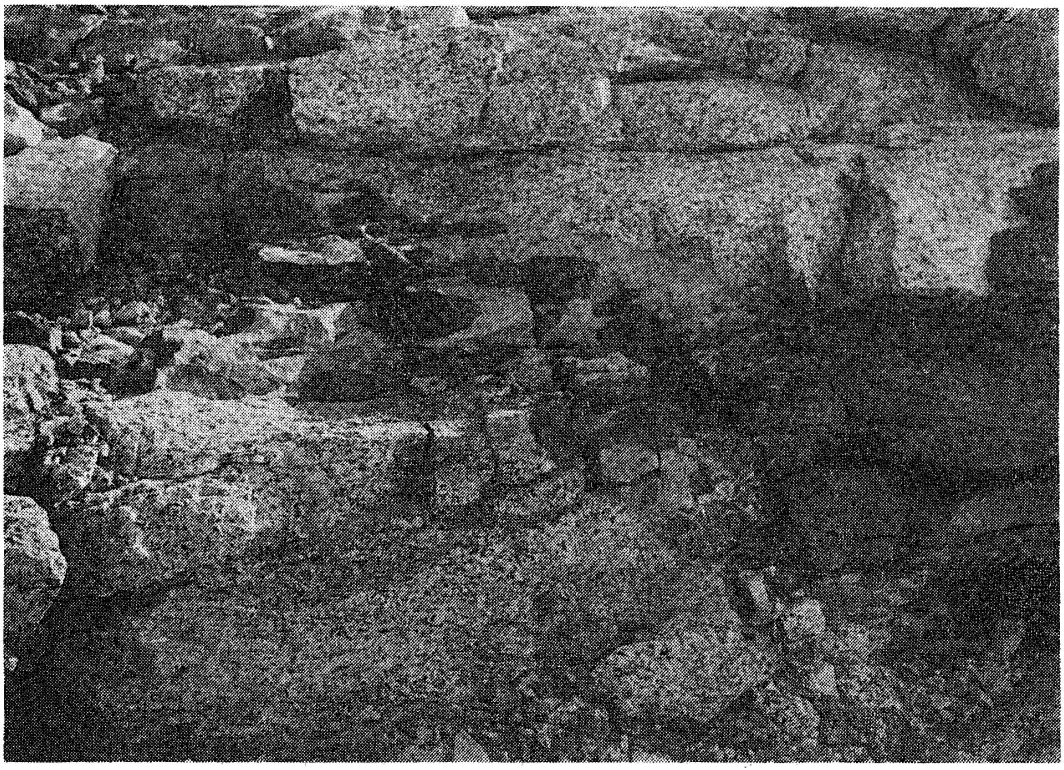

Fig. 14. Microcline porphyroblastic gneiss is cut by metabasite (Type II) which is followed by granitic dyke intrusion along the metabasite, resulting in agmatite at the later stage (Nunatak II).

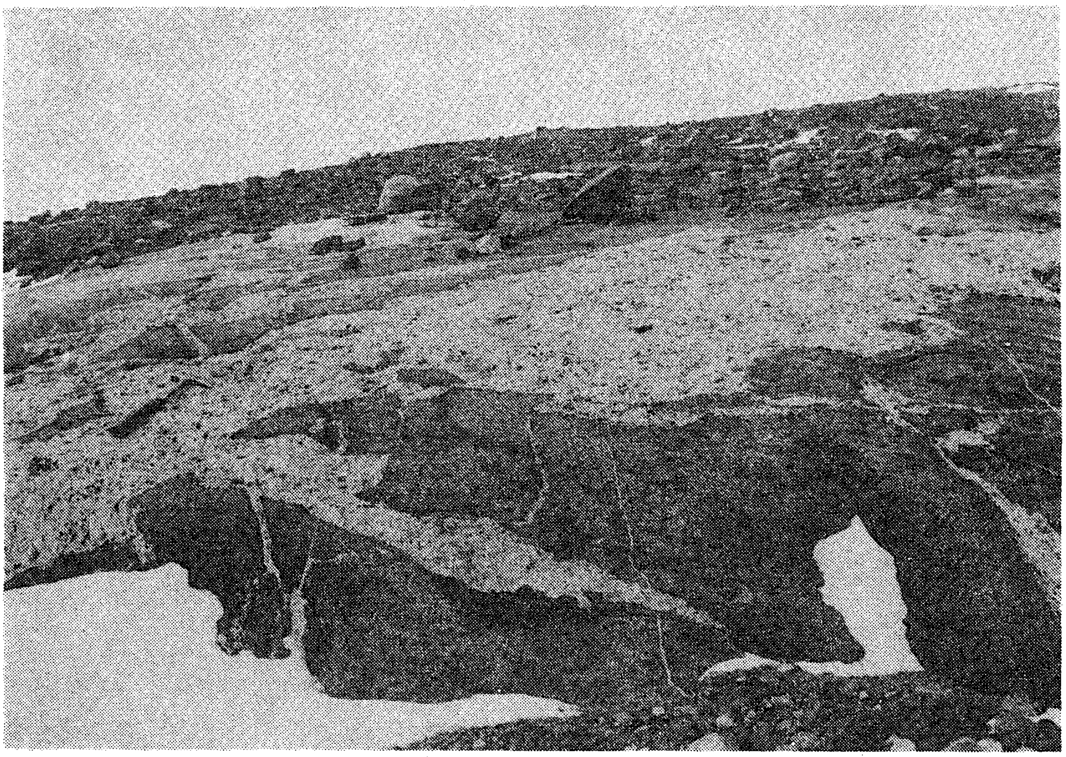

Fig. 15. Irregular pool of granitic pegmatite in biotite gneiss (Nunatak VI).

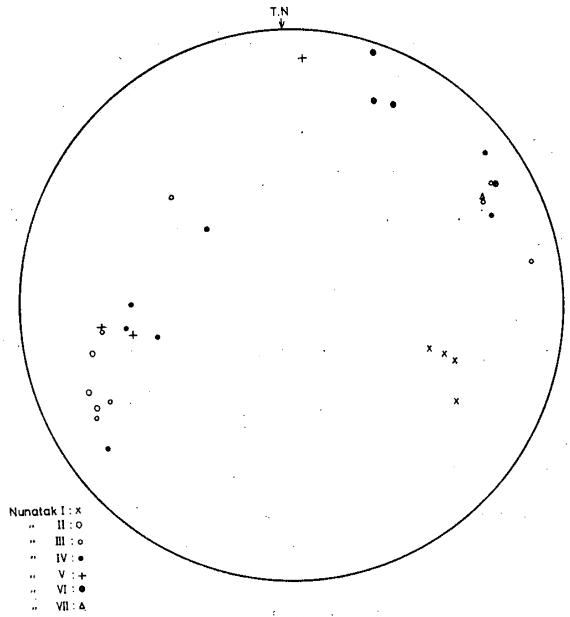

Fig 16. Poles of measured foliation plotted on Schmidt's net.

Table. 1. Modal compositions of the rocks. (Volume per cent)

	1	2	3	4	5	6	7	8
Quartz	28.7	13.6	47.5	16.9	23.5	17.3	5.0	18.6
Potassium feldspar	22.0	25.5	23.6	5.9	41.3	17.7	31.0	30.1
Plagioclase	41.5	34.3	24.9	45.3	27.5	25.2	15.7	32.0
Biotite	6.0	11.6	2.8	22.7	3.4	24.9	34.8	12.5
Hornblende	—	10.0	0.1	2.5	2.7	9.0	—	5.4
Clinopyroxene	—	1.6	—	—	—	—	12.2	—
Myrmekite	0.9	0.6	0.3	tr.	1.0	0.3	—	0.8
Sphene	—	0.8	tr.	tr.	—	3.0	1.2	0.5
Zircon	tr.	0.4	tr.	tr.	tr.	tr.	tr.	tr.
Apatite	0.1	1.1	0.1	2.3	0.4	1.7	tr.	0.1
Opaque	0.1	0.9	0.6	3.5	0.1	1.0	tr.	—
Others*	0.7	0.1	0.1	0.9	0.2	0.1	0.1	tr.

1. Hornblende-biotite gneiss (leucosome) (No. 121402)
2. 〃 (melanosome) (No. 121407)
3. Quartzo-feldspathic gneiss (No. 121609)
4. Biotite gneiss (No. 121709)
5. Microcline porphyroblastic gneiss (No. 121706)
6. Hornblende-biotite metabasite (Type I) (No. 121707)
7. Pyroxene metabasite (Type I) (No. 121406)
8. Hornblende-biotite metabasite (Type II) (No. 121403)

* mainly sericite and chlorite

foliated structure.

Melanosome with a granoblastic texture is composed mainly of plagioclase, potassium feldspar, quartz, biotite and hornblende. It is also characterised by the presence of relict clinopyroxene which occurs as fine greenish grains, 0.1–0.2 mm in size, and partly altered to hornblende. Apatite and sphene are abundant. The leucosome consists of plagioclase, quartz, potassium feldspar; among them plagioclase is predominant and quartz is slightly elongated. No hornblende occurs in leucosome.

The petrographic properties of hornblende-biotite gneiss are shown in Table 2.

Table 2. Petrographic properties of hornblende-biotite gneiss

	Potassium feldspar	Plagioclase	Quartz	Biotite	Hornblende	Clino-pyroxene	Others
Leucosome (No. 121402)	microcline 0.3mm in size, 1.4mm max.	0.6mm–0.8 mm in size, 1.4mm in max., polysynthetic twin, An 18–25.	0.2mm in size, 1.5mm in max., slightly elongated, wavy extinction.	0.3mm in length, 0.6 mm in max., X–pale brownish yellow Y–dark brown Z–dark brown.			myrmekite, apatite, sericite, chlorite, zircon, opaques.
Melanosome (No. 121407)	microcline 0.2–0.8mm in size.	0.5–1.0mm in size, polysynthetic twin, An 23–30.	0.2–0.5mm in size, wavy extinction.	0.2–0.4mm in length, 1.0mm in max., flaky fragments, X–pale brownish yellow Y–brown Z–dark brown.	0.1–0.6mm in size, 1.5 mm in max., poikilitic, X–light brown Y–brownish yellow Z–dark green, 2Vx =54°–61°.	0.1–0.2mm in size, fine fragments partly altered to hornblende 2Vz=52°–68°.	apatite, sphene, zircon, opaques.

3.2. Granitic gneisses

Granitic gneisses occur in the whole area except Nunatak I.

Quartzo-feldspathic gneiss is the most predominant rock species. The rock is medium- to coarse-grained, with a pale pinkish colour. The foliation expressed by elongated quartz grains and preferred orientation of the constituent minerals is relatively clear.

In Nunatak III, melanocratic fine-grained parts in the quartzo-feldspathic gneiss occur as bands of a few metres in width and show intense foliation.

Quartzo-feldspathic gneiss is composed of quartz, plagioclase, potassium feldspar, biotite, hornblende and accessories. This rock shows a granoblastic texture with extremely elongated quartz grains.

Biotite gneiss, fine to medium in grain size and showing weak foliation, is developed sporadically in Nunataks IV, V, VI and VII. Its relation to the quartzo-feldspathic gneiss is not clear due to the covering morainic debris, but the biotite gneiss appears to occur always in association with the metabasite bands. It occurs also as a melanocratic part of the quartzo-feldspathic gneiss showing schollenic and schlierenic structures (Fig. 17).

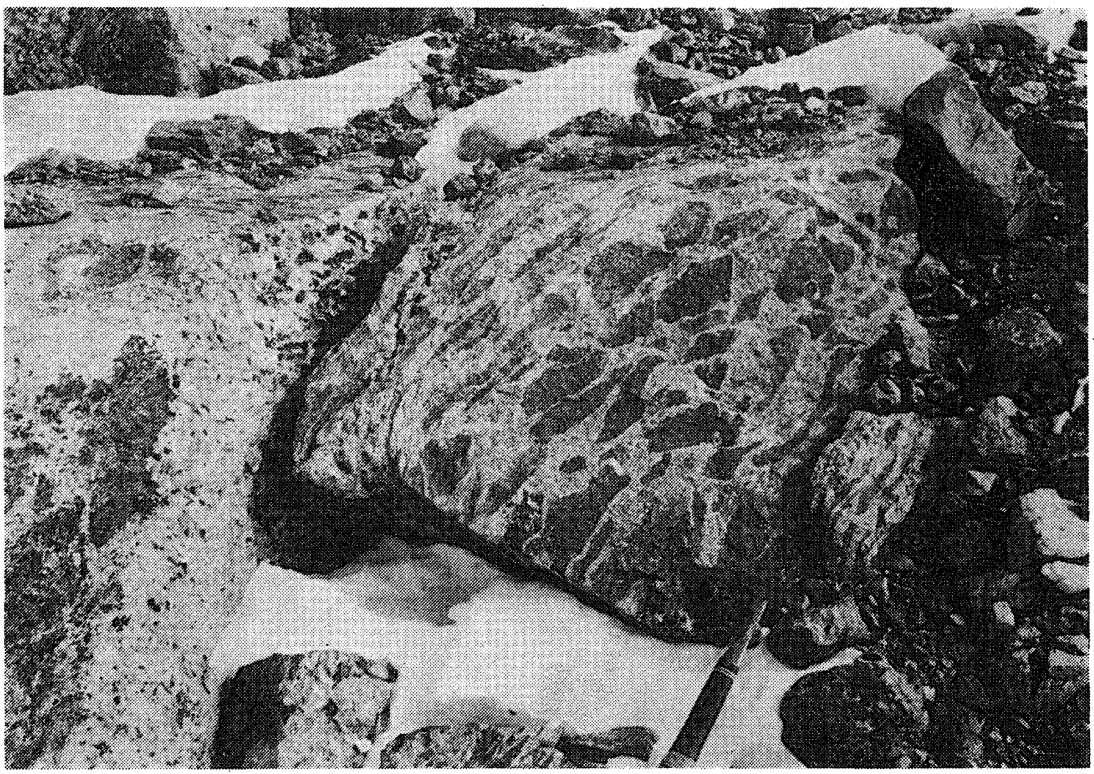

Fig. 17. Schollen structure of granitic gneiss (Nunatak IV).

The constituent minerals of the biotite gneiss are identical with those of the quartzo-feldspathic gneiss; plagioclase and biotite are abundant in the former, and so are quartz and potassium feldspar in the latter. Plagioclase is partly altered to sericite and sometimes shows albite-Carlsbad twins. Biotite and hornblende have a partial poikiloblastic texture. Particularly biotite exhibits "myrmekite-like" intergrowth with quartz. Apatite is dominant.

Microcline porphyroblastic gneiss is sporadically found in the quartzo-feldspathic gneiss area. The most conspicuous feature of the rock is the presence of large

Table 3. Petrographic properties of granitic gneisses

	Potassium feldspar	Plagioclase	Quartz	Biotite	Hornblende	Others
Quartzo-feldspathic gneiss (No. 121609)	0.4mm in size, 1.4 mm in max., stringlet-bead shaped perthite, microcline, 0.2mm in size, granular.	0.3–0.6mm in size, 1.0mm in max., miclocline inclusions frequent, polysynthetic twin, sericitization, An 23–26.	0.2–0.4mm in size, granular. 1–4mm in size, elongated, strong wavy extinction.	0.1–0.2mm in length, 0.8mm in max., X–pale yellow Y–yellowish brown Z–dark brown.	very small amounts, 0.2mm in size, X–pale greenish yellow Z–bluish green.	myrmekite, apatite, sphene, allanite, sericite, chlorite, opaques.
Biotite gneiss (No. 121709)	microcline perthite, stringlet shape, 0.6–1.0mm in size, sericitization.	0.5–1.0mm in size, polysynthetic twin, albite-Carlsbad twin, quartz inclusion, antiperthite, sericitization, An 23–28.	0.2mm in size, wavy extinction.	0.2–1.0mm in length, partly poikilitic, quartz inclusion, X–pale brownish yellow Y–yellowish brown Z–dark brown.	rare poikilitic fragments, partly altered to biotite, X–pale yellow Y–dark brown Z–brownish green, 2Vx=50°–68°.	myrmekite, apatite, sphene, zircon, sericite, opaques.
Microcline porphyroblastic gneiss (No. 121706)	microcline perthite, 0.1–0.4 mm in size, 7–10 mm in porphyro-blast, including quartz, surrounded by fine grains of quartz, plagioclase and microcline.	0.1–0.5mm in size, polysynthetic twin. 0.5–2.0mm in size, drop shaped antiperthite, deformation twin, An 22–28.	0.1–0.2mm in size, 0.5–1.0mm in size, slightly elongated, strong wavy extinction.	0.2–1.0mm in length aggregate with hornblende, X–pale brown Y–brown Z–reddish brown.	0.2–1.0mm in size, 1.5mm in max., partly altered to biotite, X–light yellowish brown Y–brownish green Z–light green, 2Vx=42°–61°.	myrmekite, apatite, sphene, zircon, opaques.

microcline porphyroblasts, which often attains up to a few centimetres in size. Sometimes microcline porphyroblastic gneiss is developed along the boundary between granitic gneisses and the metabasite having parallel foliation to that of the country rock. The gneiss is coarse-grained and contains slightly pinkish microcline. In handspecimens, the foliation is faint, but in the outcrops it is distinctly shown by the elongation of porphyroblasts.

In thin sections, the microcline porphyroblastic gneiss is noticed to contain microcline porphyroblasts, 7 to 10 mm in grain size, plagioclase, quartz and a small amount of biotite and hornblende, 0.5 to 1.0 mm in grain size. The matrix, about 0.2 mm in grain size, surrounds the above porphyroblasts. All of potassium feldspar are microcline perthite of string type. Larger grains of plagioclase are antiperthite of drop type and sometimes exhibit deformed twins. Quartz grains are slightly elongated and exhibit wavy extinction. Fine-grained matrix is composed mainly of equigranular quartz, plagioclase and microcline. Hornblende is partly altered to biotite. Myrmekite is present.

The petrographic properties of granitic gneisses are shown in Table 3.

3.3. Metabasite

The metabasite of Type I derived from concordant basic sheet is found throughout the whole area. In Nunatak I where hornblende-biotite gneiss is developed,

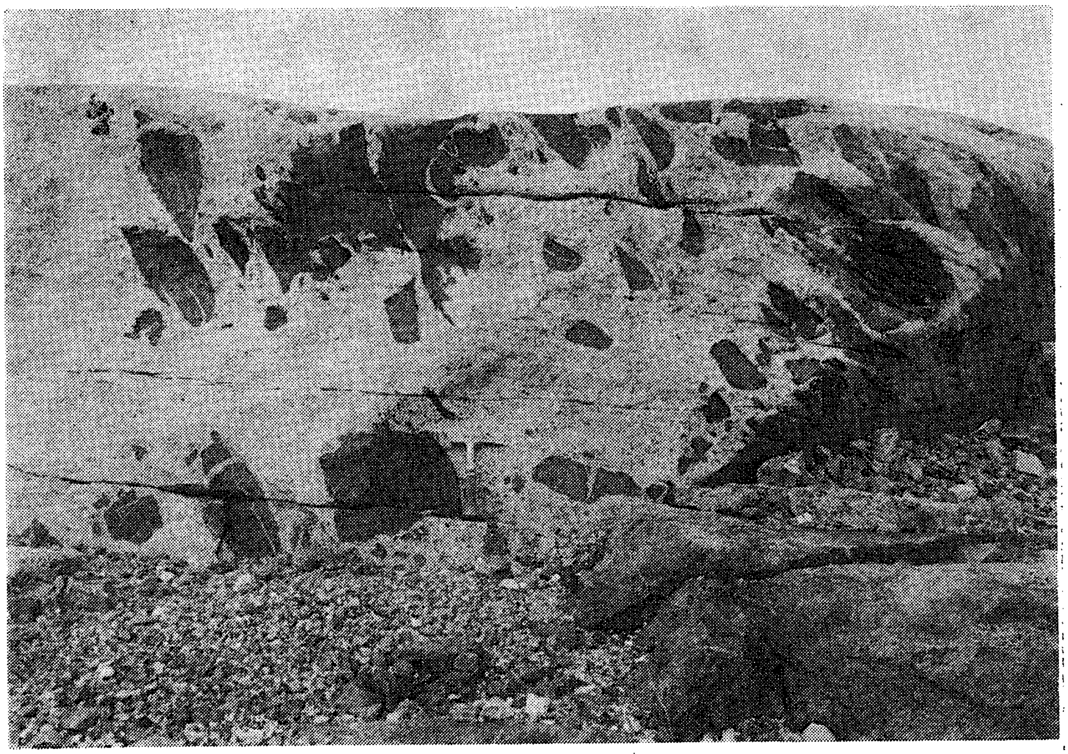

Fig. 18. Agmatitic structure of granitic gneiss (Nunatak VI).

Table 4. Petrographic properties of metabasites

	Potassium feldspar	Plagioclase	Quartz	Biotite	Hornblende	Clinopyroxene	Others
Hornblende-biotite metabasite (Type I) (No. 121707)	0. 4mm in size, 0. 8mm in max., stringlet-bead shaped perthite.	0. 2–0. 6mm in size, 1. 0mm in max., An 18–21.	0. 1–0. 3mm in size.	0. 05–3. 0mm in length, X–pale brownish yellow Y–dark brown Z–dark yellowish brown.	0. 05–0. 4mm in size, 0. 8mm in max., poikilitic, X–pale greenish yellow Y–brownish green Z–light green, $2Vx=54°–68°$.		myrmekite, sphene, apatite, opaques.
Pyroxene metabasite (Type I) (No. 121406)	0. 1–0. 2mm in size, stringlet shaped perthite.	0. 2mm in size, polysynthetic twin, An 21–25.	rare.	0. 1–0. 2mm in length. 2–5mm in length, X–pale yellow Y–brown Z–yellowish brown.		0. 1mm in size, 0. 8mm in max., many fine grains scatter, $2Vx=56°–64°$.	sphene, zircon.
Hornblende-biotite metabasite (Type II) (No. 121403)	microcline, 0. 6mm in size.	0. 4–0. 6mm in size, 1. 2mm in max., polysynthetic twin, deformation twin, An 19–22.	0. 1–0. 6mm in size, 1. 0 mm in max., slightly elongated.	0. 1–0. 8mm in length, generally 0. 4–0. 6mm flaky shape, X–pale brownish yellow Y–yellowish brown Z–dark brown.	0. 2–0. 6mm in size, poikilitic, X–pale brownish yellow Y–brownish green Z–light green, $2Vx=47°–52°$		myrmekite, sphene, apatite, zircon.

the contact between metabasite and the country rock is sharp, but in other nunataks it is ambiguous and shows gradual transition from metabasite to granitic gneisses. Sometimes the microcline porphyroblastic gneiss occurs there. Locally the metabasite shows an agmatitic structure in the granitic gneisses (Fig. 18). The metabasite is cut across by many aplitic veins which are parallel to the foliation.

On the other hand, the metabasite dyke of Type II obliquely cutting the country rock has usually a clear boundary. The foliation of both types of metabasites is shown by dimensional alignment of mafic minerals and is distinct in field as well as in handspecimens.

Modal compositions of the metabasites are shown in Table 1, in which hornblende-biotite metabasite (No. 6) and pyroxene metabasite (No. 7) are of Type I. The hornblende-biotite metabasite was collected from the granitic gneisses area. Plagioclase being most abundant constituent is large in grain size up to one millimetre or more. Potassium feldspar is stringlet or bead type perthite. Microcline is absent. Sphene is abundant.

The pyroxene metabasite collected from the hornblende-biotite gneiss area is characterized by the presence of dominant clinopyroxene and a small amount of quartz.

In the metabasite of Type II, on the other hand, quartz is abundant and microcline is present.

The petrographic properties of the metabasites are shown in Table 4.

4. Conclusion

From the facts described above, the rocks of this area are considered to belong to the upper part of the amphibolite facies. They may belong to the sillimanite-almandine subfacies defined by RAVICH (1972), though sillimanite is not found in this area. The plagioclase compositions, however, are more albitic than those of RAVICH's definition.

In comparison with the rocks of the Yamato Mountains, no charnockitic rocks are found in this area.

These nunataks are located between the Yamato Mountains and the Belgica Mountains. The geology of the Belgica Mountains is composed mainly of migmatized biotite-hornblende gneiss, according to the information by the Belgian expedition (VAN AUTENBOUR *et al.*, 1972). Therefore, it can be supposed that the geology of the present area continues to that of the Belgica Mountains.

The route between the Belgica Mountains and the nunataks of the present area has not been explored, but there may exist some nunataks similar to those of the present area. It is desired that the route is traced toward the Belgica Mountains and the geology along the route is investigated in detail.

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